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THE ABORTABLE BEAM

Tune-up of the Doubler will require a fast beam-abort system which extracts the protons to a dump external to the tunnel at any beam energy. Without such a system working automatically, investigation of the Doubler properties will be severely inhibited by the possibility of beam-induced magnet quenches from which recovery will be slow. Apparently, the only practical system uses a vertical kick at the beginning of one long-straight section to place the extracting beam above a septum at the beginning of the next long-straight section. This process involves one sector where the beam traverses bad fields in the vertical portions of the magnet apertures, where the non-linear beam behavior comes from combinations of large vertical and normal horizontal displacements. How big a kick and how big a beam can we abort without losing it in this sector? After considerable arithmetic I find a surprisingly definite answer.

To reduce the variables to manageable proportions, I assumed that one started with a standard beam in which all possible combinations of horizontal amplitude and phase, vertical amplitude and phase, and momentum error could occur in the following ranges:

.15" horizontal amplitude (at normal β_{max}

.15" vertical amplitude

-.1% to +.1% $\Delta p/p$.

These restricted ranges, only perhaps 50% larger than a perfectly injected 200-GeV beam, were found to be necessary as we shall see. This beam must be safely abortable. I then inquired into the possible range for each parameter assuming only one at a time was increased with the others fixed, presuming that tuning or beam blow up would be effective in one dimension at a time. It turns out that the limits are quite sharply defined by a rapid increase in the vertical emittance.

The first step is to establish a reasonable kick amplitude. Computations used a kick centered on a point 200 inches into the clear long straight and followed the beam to a similar point in the next long straight. These are not the final locations of devices but the results will still be valid. The non-linear fields of the <u>design</u> magnet, without sextupoles or chromaticity, were used. The largest practical kick is desirable so that the septum can have some strength.

Figure 1 shows the emittance of the standard beam, at the 200" point, without distortion. Figure 2 shows the distortion of the emittance after one sector on an abort orbit of 0.8" displacement at the downstream end. I would have preferred more but the larger kicks did not allow much beam size. Figure 3 gives the standard beam emittance for a 0.9" kick, showing a greatly increased distortion. This latter kick provides no added tolerance for tuning. My standard abort orbit, then, starts with a .197-mrad kick and has a 0.8" displacement and <u>-.192-mrad angle</u> at the downstream (200") point. It also has a small outward motion - .0008" and .14 mrad - because of the reduced bending field with large vertical displacements, but this can be neglected. The abort orbit can be calculated from normal phase-amplitude parameters.

The next three diagrams show the results for the one-at-a-time increase of the parameter ranges. The momentum and horizontal amplitude ranges, as judged by avoiding sharp increases in vertical emittance, are quite generous - ±.3% and 0.8" amplitude. The maximum vertical amplitude of .25" is not, but it does leave .25" clear for the septum, which is good. I emphasize that larger vertical beams can circulate but, since they cannot be aborted, they are dangerous and should probably be eliminated by a suitable aperture. Radiation from this aperture would be a signal for an abort trigger. As a consequence of the limited height of an abortable beam, we can profitably and safely reduce the vertical aperture of kickers and septa below main-ring standards and thus obtain the necessary higher fields.

The last figure is included to give some feeling for the complexity of this analysis.

In conclusion, the abortable beam has:

Abort orbit 0.8" kick at septum after 1 sector,

Standard Beam Ranges: .15 horizontal amp.

.15 vertical amp.

$-.1\%$ to $+.1\%$ $\Delta p/p$,

plus one-at-a-time ranges of:

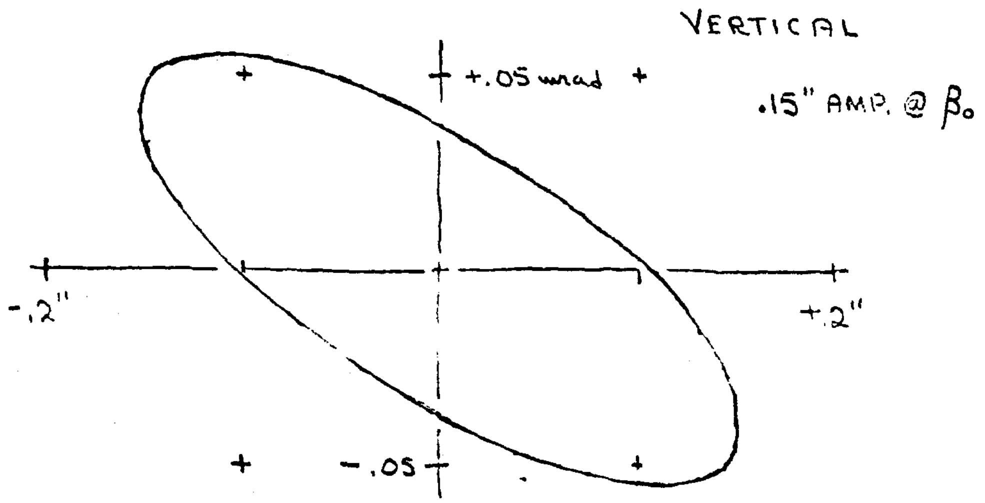
.8" horizontal amp.

or .25" vertical amp.

or $\pm .3\%$ $\Delta p/p$.

All amplitudes measured at normal β_{max}.

STANDARD BEAM EMITTANCES WITHOUT DISTORTION



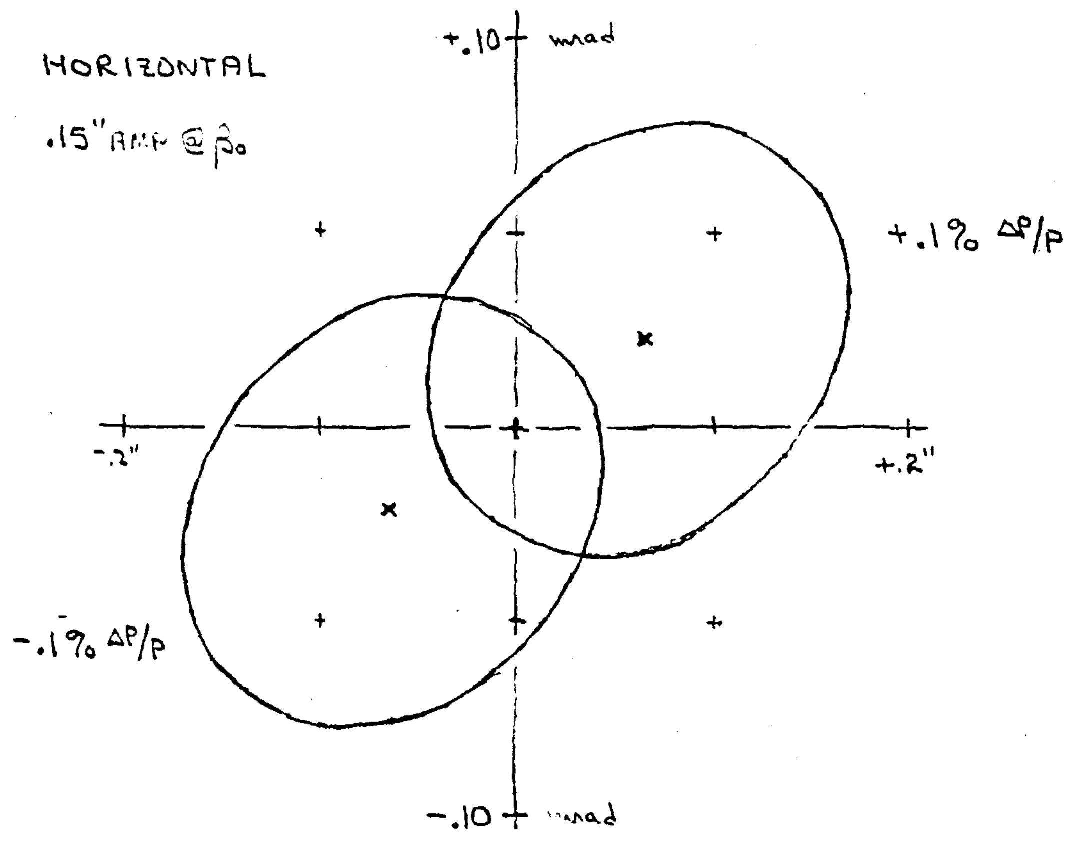
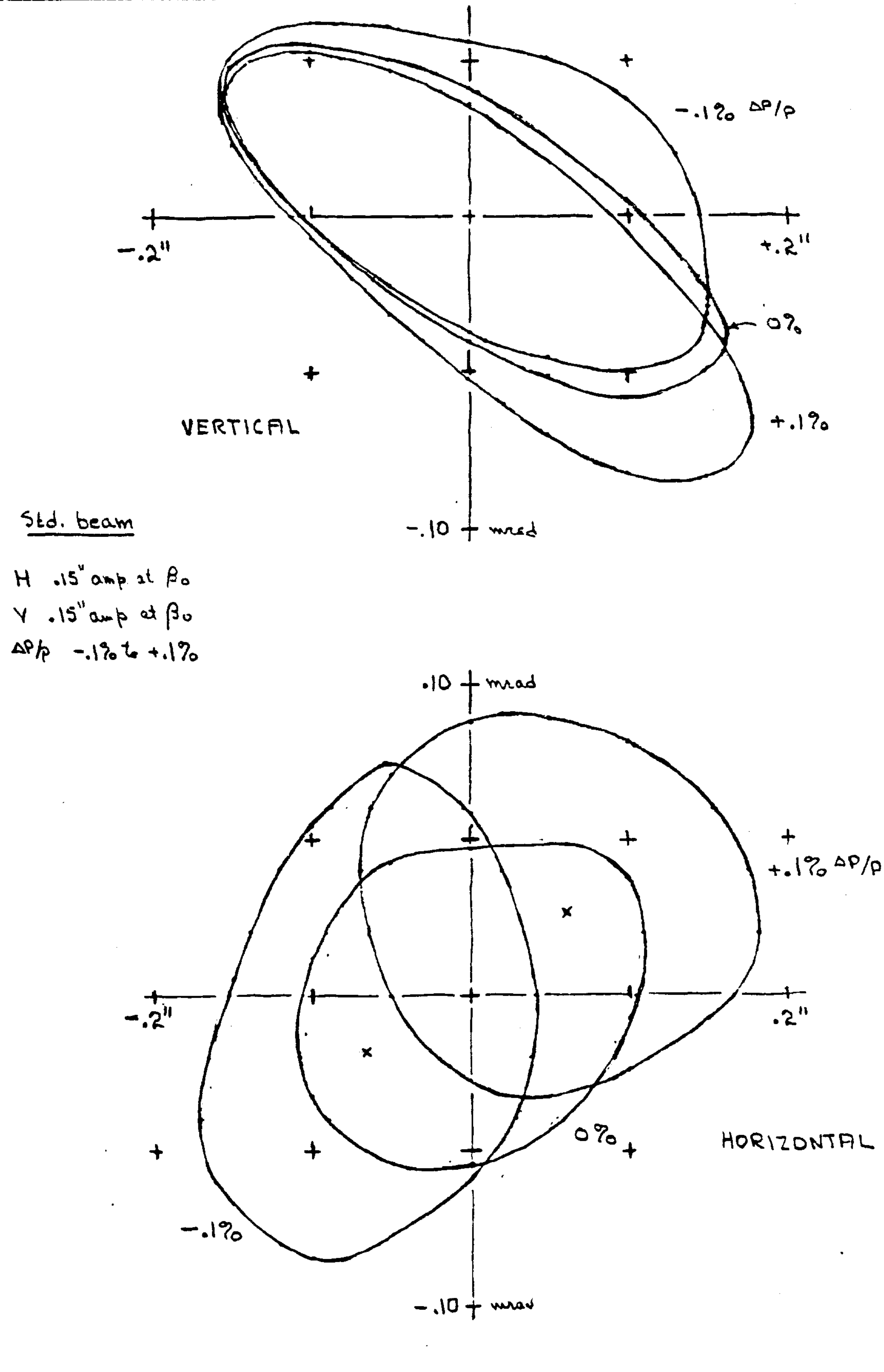


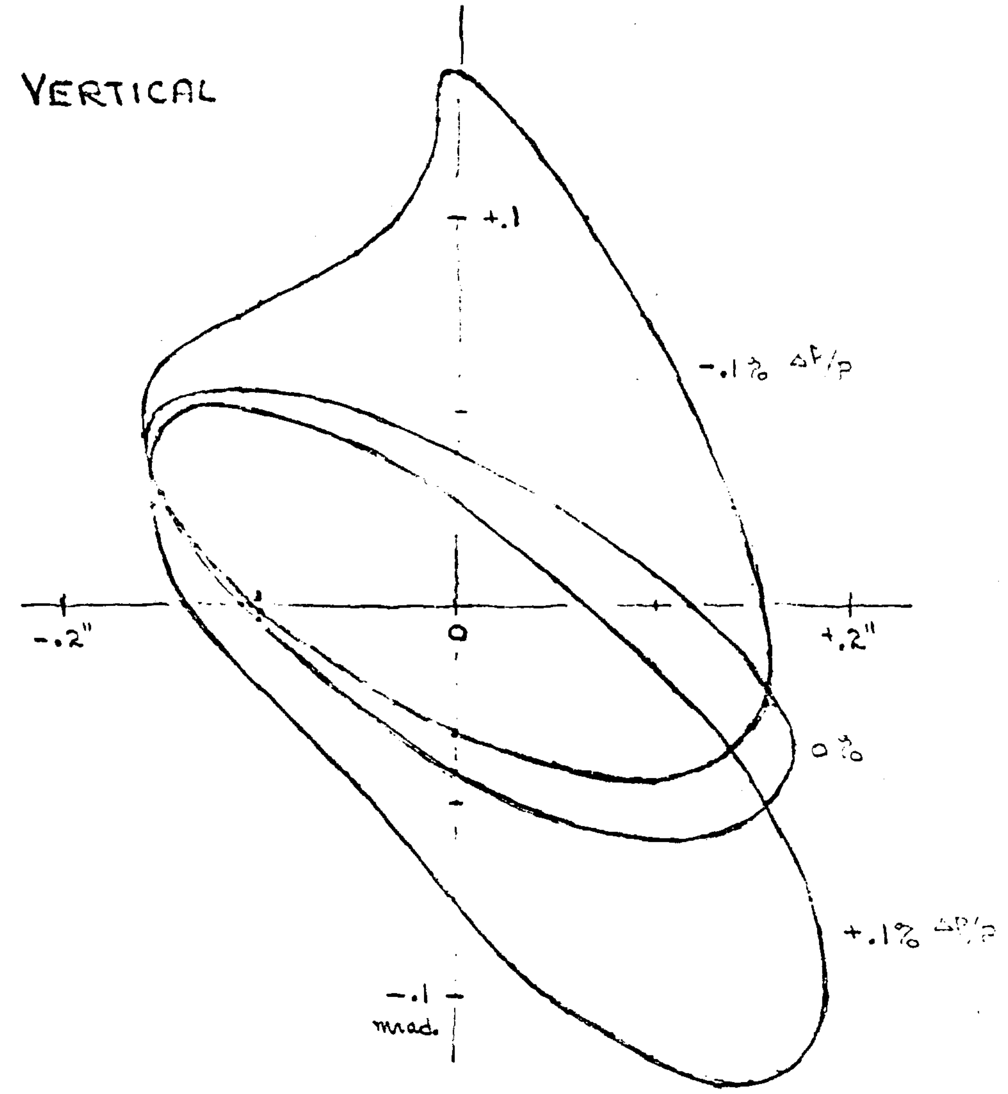
Figure 1.



STANDARD BEAM after one sector on a

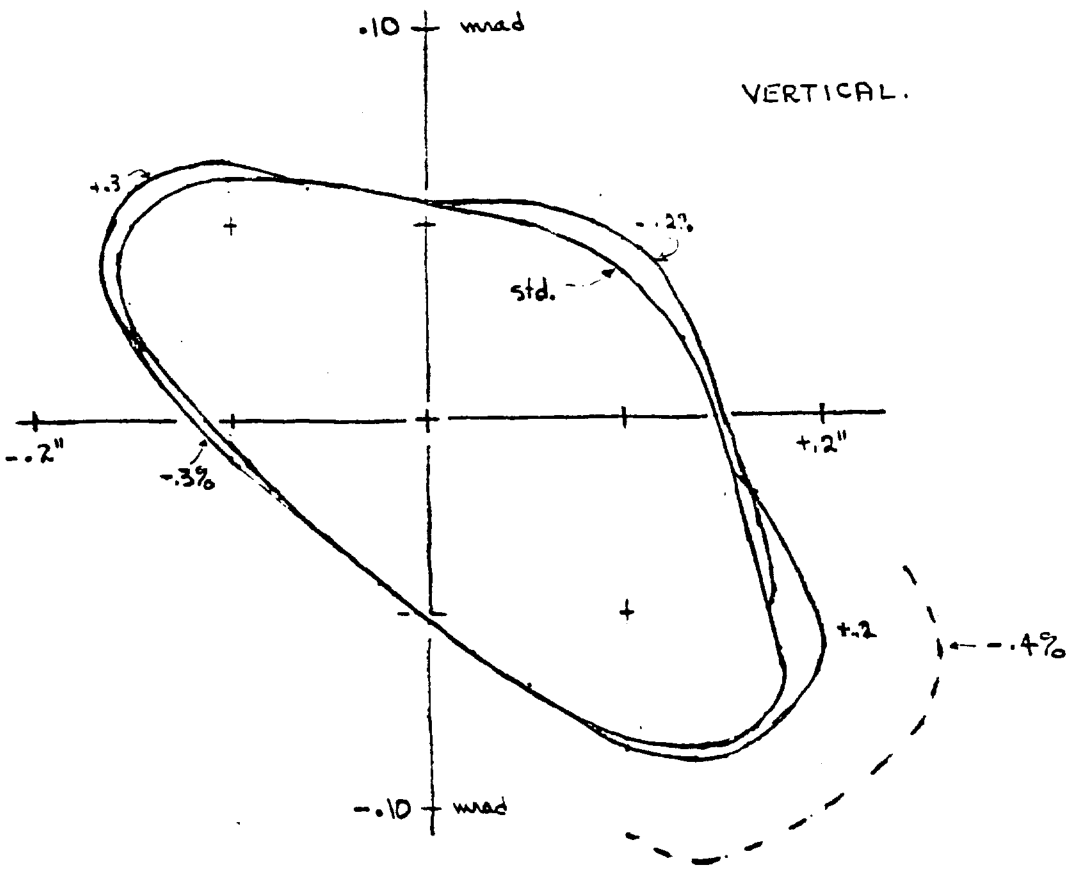
0.8" VERTICAL ABORT KICK.

Figure 2.



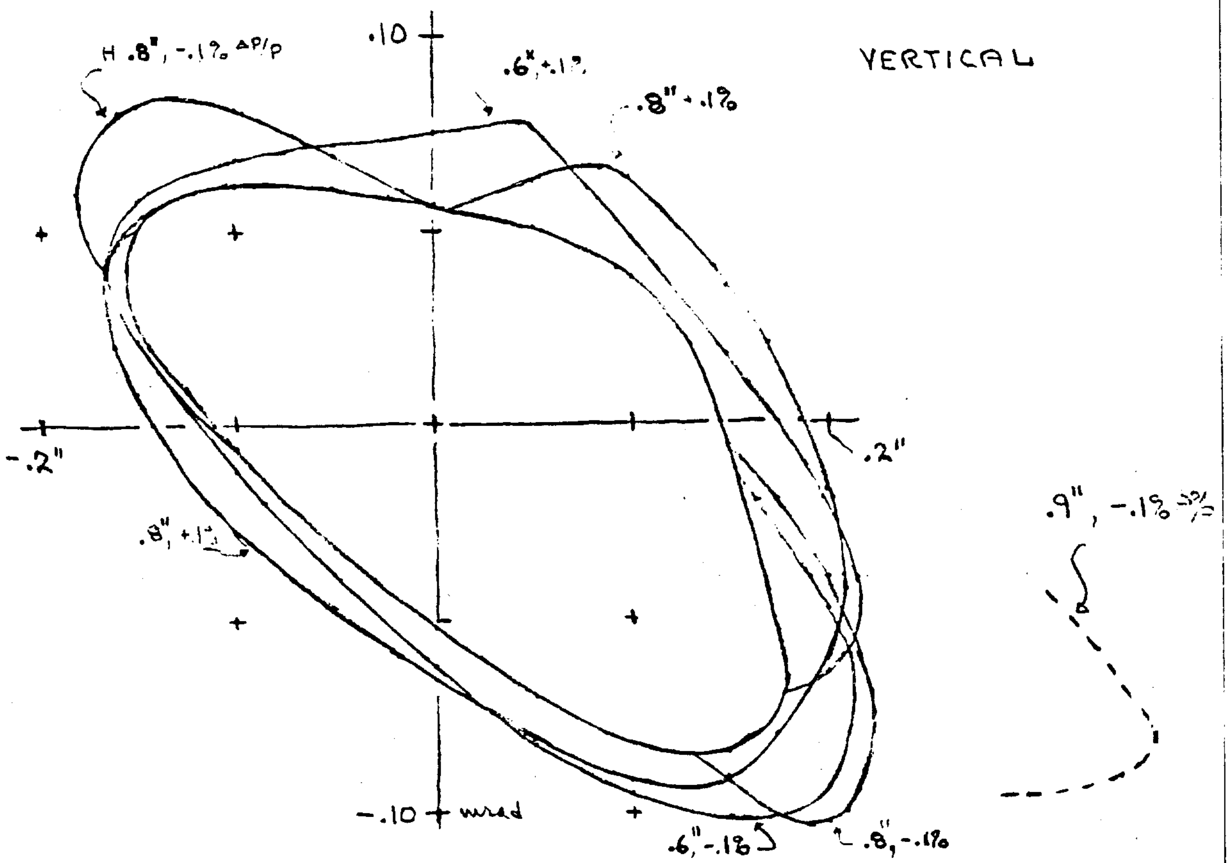
STANDARD BEAM AFTER ONE SECTOR ON A 0.9" ABORT ORBIT. NOTE GREATLY INCREASED DISTORTION.

figure 3



EFFECT OF INCREASING MOMENTUM ONLY IN STD. BEAM. (.8" ABORT ORBIT)

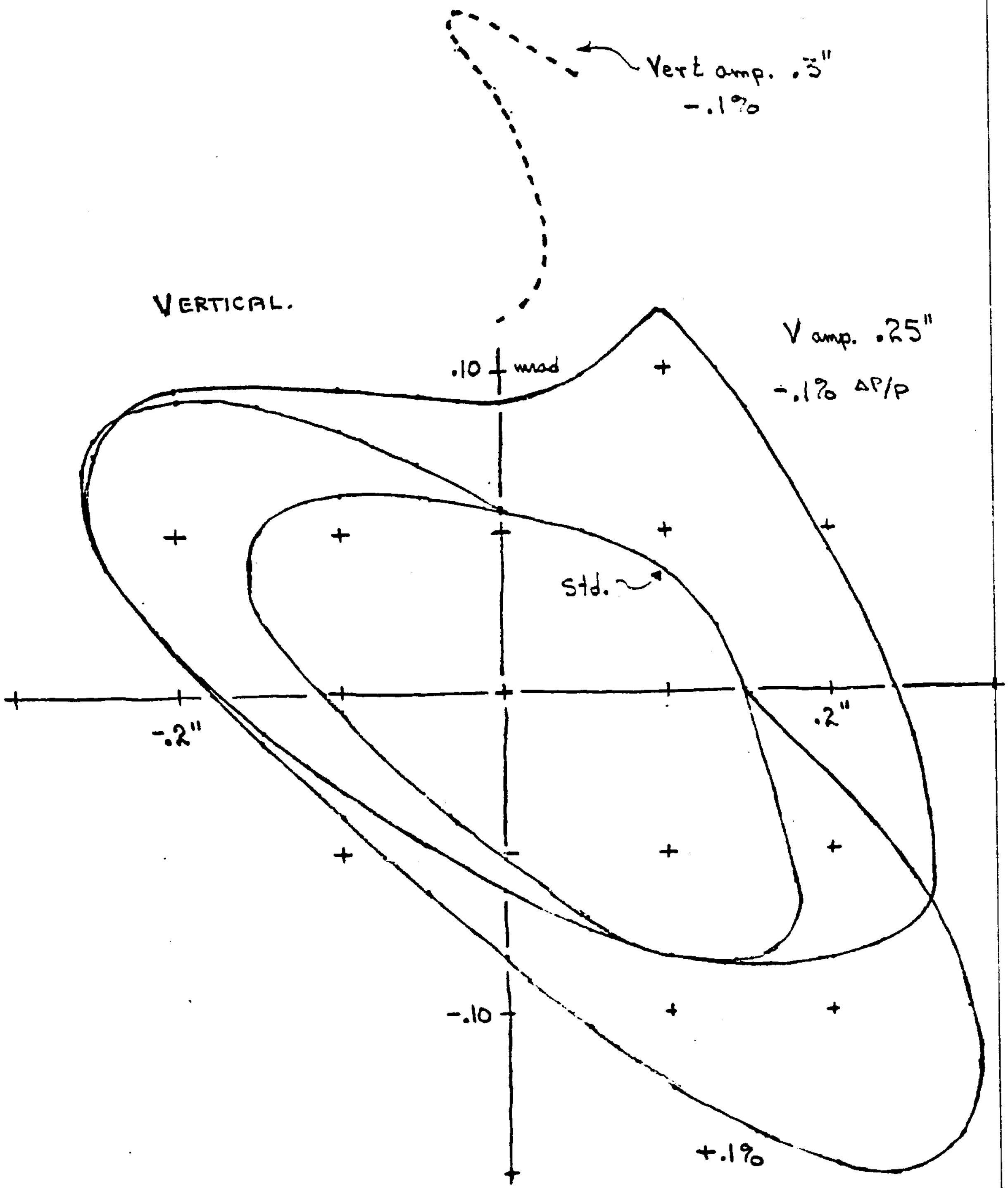
figure 4.



FOR HORIZONTAL EMITTANCE USE .85" AMP OUT for .8" AMP IN, and normal functions.

EFFECT OF INCREASING HORIZONTAL AMPLITUDE IN STANDARD BEAM. (.8" ABORT ORBIT)

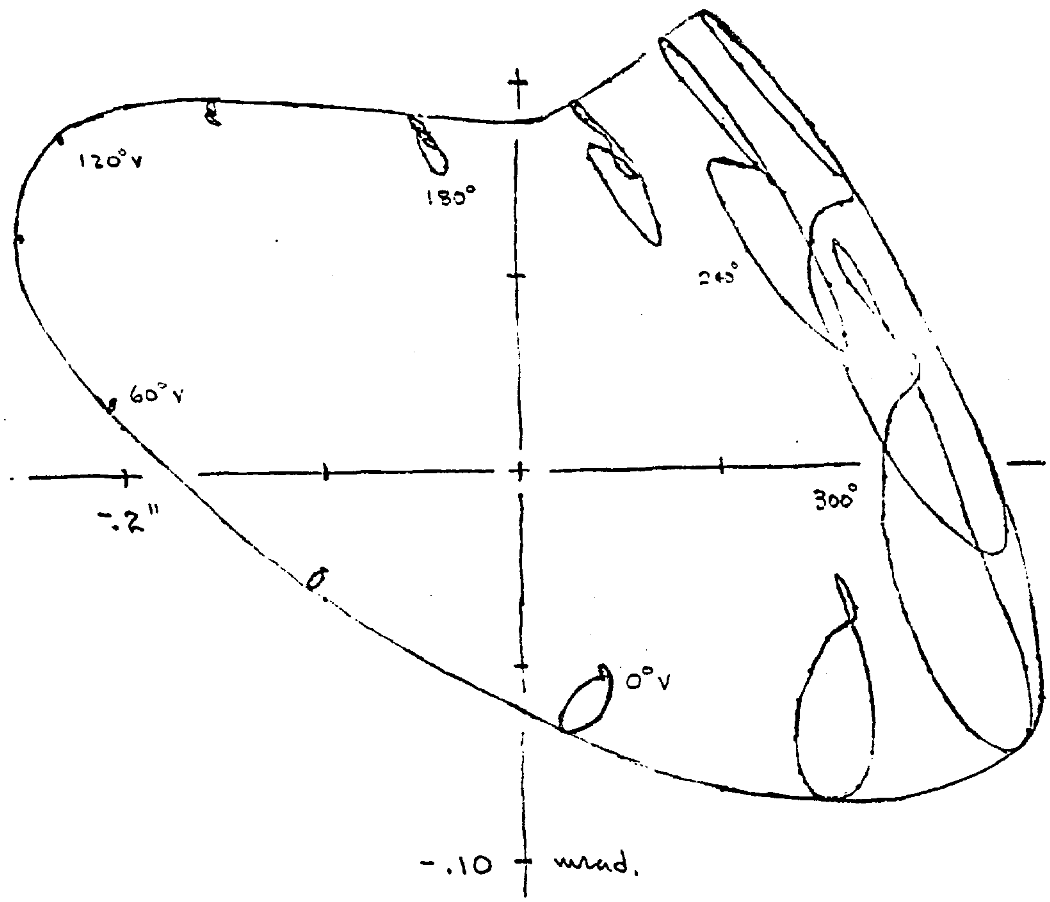
figure 5.



EFFECT OF INCREASING VERTICAL AMPLITUDE ONLY IN STANDARD BEAM. (.8" ABORT ORBIT)

figure 6.

AN EXAMPLE



VERTICAL EMITTANCE for -.1% ΔP/P, VERT. AMP .25" and HORIZ AMP. .15" (at their β_0's). Each small figure traces emittance variation with phase of the horizontal for a particular phase of the vertical. Only the envelope is shown on other diagrams.

Figure 7